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# AN OBJECTIVE METHOD OF FORECASTING WINTER RAIN FOR PORTLAND, OREGON

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## INTRODUCTION

This paper reports results of a study made for the purpose of developing an objective method for forecasting winter rain at Portland, Oregon, 24–48 hours in advance. The study was undertaken simultaneously with a similar investigation by Vernon [1] on forecasting rain at San Francisco. It was inspired largely by the need for improved forecasts extending beyond 24 hours for use in operational planning by agriculture, industry, and transportation. This method of forecasting is not a substitute for present forecasting techniques or thorough analyses of the physical processes of the atmosphere, but if used in conjunction with these it can be a valuable forecasting aid. These results should be used cautiously until more cases have been studied in order to find those variables which will produce the highest degree of forecasting skill.

Previous studies attacking the problem of forecasting rain on the west coast resorted to map typing, and the method of forecasting set forth in this paper also depends on proper typing of maps. Reed [2] was the first to publish a map typing system for the northeast Pacific Ocean, and in a sense it is the parent of those which followed. His system was based on the direction of the principal air currents over the northeast Pacific and each map was classified as N, NW, W, SW, S, or E, following in general the principles set forth by Abercromby [3] who earlier had developed a method of typing maps in the north Atlantic Ocean. Reed's system is descriptive and requires the subjective impressions of forecasters; nevertheless it is an excellent system, and one that has been used regularly since it was published in 1932. Brown [4], in 1943, published a paper on rainfall forecasting for Los Angeles. He considered weather types which were modifications of Reed's types, and his method of forecasting is partly objective. In the same year the California Institute of Technology [5] published an elaborate and detailed system of classifying maps. This development was based largely on the configuration of the pressure field with the position and intensity of the Pacific High forming the keystone. Then in 1946, Thompson [6] developed an objective method of forecasting rain at Los Angeles 6–24 hours ahead. This paper differs from Thompson's in that it aims to forecast rain for Portland 24–48 hours in advance thus providing a more useful service in operational planning.

Typing weather maps by individual deduction results in differences of opinion since a vast number of maps are reasonably similar yet have significant differences which are not readily recognizable. It was the purpose of the investigation outlined here, in conjunction with Vernon's study, to type maps by numerical means as the first step of an objective method of forecasting rain. Accomplishing that, the second step was to find suitable pressure gradients or other variables which would separate the "rain" from the "no-rain" cases in each type.

The 1300 GMT maps of the Historical Weather Map series [7] for the ten months of January and February 1932, 1933, 1935, 1936, and 1938 formed the basis for this study. These 297 maps were selected because they represent days during wet and dry months and months with average winter rainfall. In addition they represent a variety of weather types. A "rain" day is defined as one on which a measurable amount of rain fell in the official gage in Portland between midnight and midnight of the following day—20 to 44 hours after map time. Traces counted as "rain" only if measurable rain fell on the day preceding or following the day for which the forecast was made. A few other winter months were used for test purposes and the results from 4 of these, December 1930 and 1933, and January and February 1937, appear in a later section. Although the study was confined to the months of January and February, equally good results have been obtained in December and the results outlined here should be restricted to the main part of the rainy season.

## INVESTIGATION

### CIRCULATION INDICES AND MAP CLASSES

The first step in the investigation was to measure the meridional and zonal circulation by means of pressure gradients on the theory that atmospheric currents follow established patterns and the principal flow patterns usually are persistent for long periods. The areas in which these measurements were made encompass a large pressure field and extend far upwind from the west coast. By applying synoptic experience certain geographical coordinates were

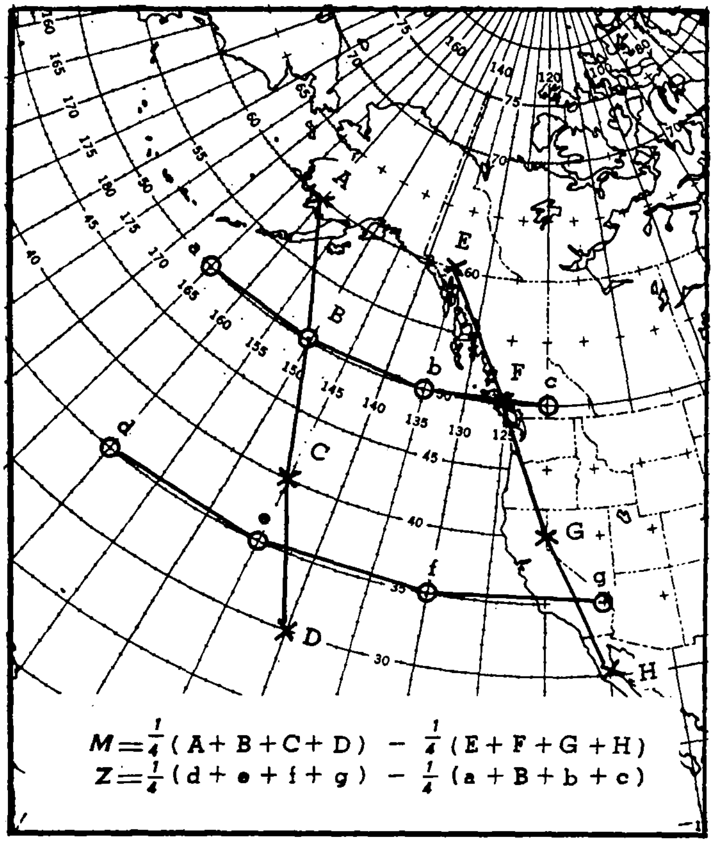


FIGURE 1.—Map showing location of points for which sea level pressures are obtained for computing meridional (M) and zonal (Z) indices.

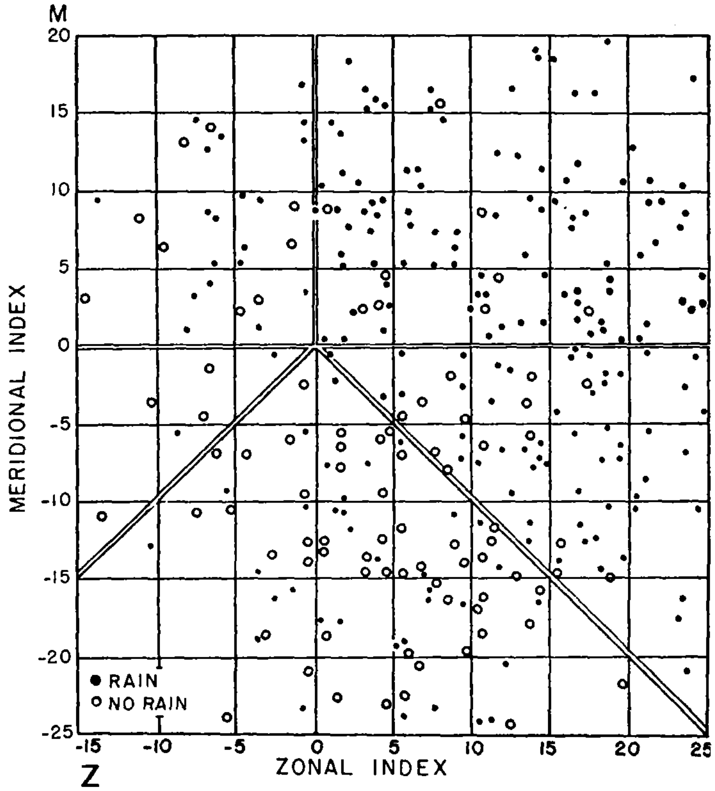


FIGURE 2.—Scatter diagram showing cases from original data of rain days and no-rain days plotted according to their respective meridional and zonal indices. The double lines divide the cases into 5 classes. (See fig. 3.)

selected in these areas which would define the several predominating flow patterns and the map types numerically. The coordinates selected for this purpose are shown on the map in figure 1. The difference between the means of the pressure at points ABCD and at EFGH gives an adequate index of the meridional flow (M). Expressed symbolically:

$$M=\frac{1}{4}(A+B+C+D)-\frac{1}{4}(E+F+G+H)$$

If this difference is positive the meridonal flow is from north to south but if the difference is negative the flow is towards the north.

The coordinates which are used to measure the zonal flow are indicated in figure 1 by points defg and points aBbc. The difference between the means of the pressures at the points along latitude 35° N. and latitude 50° N. gives a satisfactory index of the zonal circulation (Z):

$$Z=\frac{1}{4}(d+e+f+g)-\frac{1}{4}(a+B+b+c)$$

When this difference is positive the latitudinal flow is from west to east, and when negative, from east to west; the magnitude of the difference is an indication of the strength of the zonal circulation.

Algebraic relationships between the values of the meridional and zonal indices may be used to classify maps, numerically, into types. Abnormal circulation patterns such as "northerly" and "southerly" produce, respectively, positive and negative meridional values numerically larger than numerical values of the zonal indices. On the other hand a strong westerly circulation produces a positive zonal index much larger than the numerical value of the meridional index. Such relationships as these were used for classifying the surface weather maps examined in this study by plotting for each map a dot (rain day) or open circle (no-rain day) on rectangular coordinates

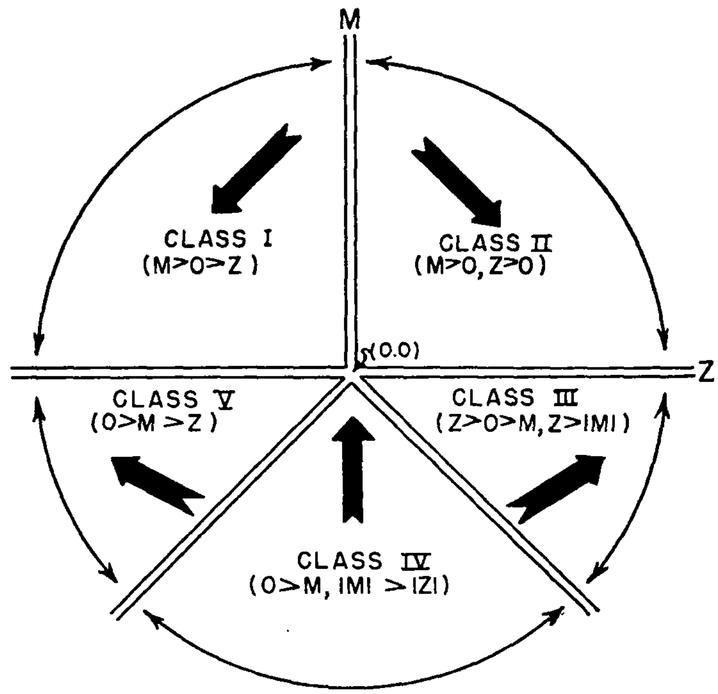


FIGURE 3.—Schematic diagram showing algebraic relationship between meridional and zonal indices for each of the 5 map classes. These divisions correspond to the divisions in figure 2. Heavy arrows indicate the predominant direction of flow over the area for which the indices were computed.

scaled for meridional (M) and zonal (Z) index values as shown in figure 2. Figure 2 then was divided by the double lines into 5 sectors in order to separate the plotted data into 5 map types or classes. As shown in figure 3, these 5 classes are defined by algebraic relationships between M and Z. The 297 maps used in this investigation thus were segregated as follows:

| Class | Relationship between indices [1] | Number of maps | Rain days [2] | No-rain days |
|---|---|---|---|---|
| I | (M>0>Z) | 28 | 19 | 9 |
| II | (M>0, Z>0) | 106 | 96 | 10 |
| III | (Z>0>M, Z>/M/) | 70 | 55 | 15 |
| IV | (0>M, /M/>/Z/) | 87 | 33 | 54 |
| V | (M and Z<0, /Z/>/M/) or (0>M>Z) | 6 | 2 | 4 |
| | Total | 297 | 205 | 92 |

[1] In these relationships, M and Z represent *algebraic* values. The symbols /M/ and /Z/ represent numerical or absolute values.
[2] There were almost 10 percent more rainy days in this sample than the average which, for this period, is 181 days of rain and 116 days of no rain.

The relationships between indices M and Z used for segregating maps into types differ from those used by Vernon in the cases with meridional indices greater than zero (M>0). Vernon separated this group of maps into three types: Northeasterly, Northerly, and Northwesterly, but in this paper these maps are separated into Class I (M>0>Z) and Class II (M>0, Z>0). To avoid confusion with Vernon's terminology, the word "class" rather than "type" is used.

The heavy arrows in figure 3 indicate for each class the general direction of the predominating air flow over the area for which the indices M and Z were computed. A few examples serve to make clear the relation of the index values to predominating flow. Points plotted in the upper left quadrant of figure 2 indicate "northeasterly" type maps on which meridional values are positive and zonal values negative (M>0>Z). Thus the map in figure 4 is not a pure "northerly" type but a map which contains features of both "northerly" and "easterly" types as indicated by the index values M=+4, and Z=−6. The map in figure 5 is an excellent example of a "northwesterly" type. For this map the index values are M=+11.5 and Z=+12.5, indicating a strong flow from the northwest. The map in figure 6 is a pronounced "southwesterly" type. The zonal flow is very strong (Z=+28), and the meridional flow is from south to north but rather weak (M=−4). Nearly all maps with large positive Z values and large positive M or small negative M values produced rain. A "southerly" type is shown in figure 7. The flow from south to north is strong (M=−13) while the zonal flow is very weak (Z=+1), indicating the westerly circulation is almost stagnant.

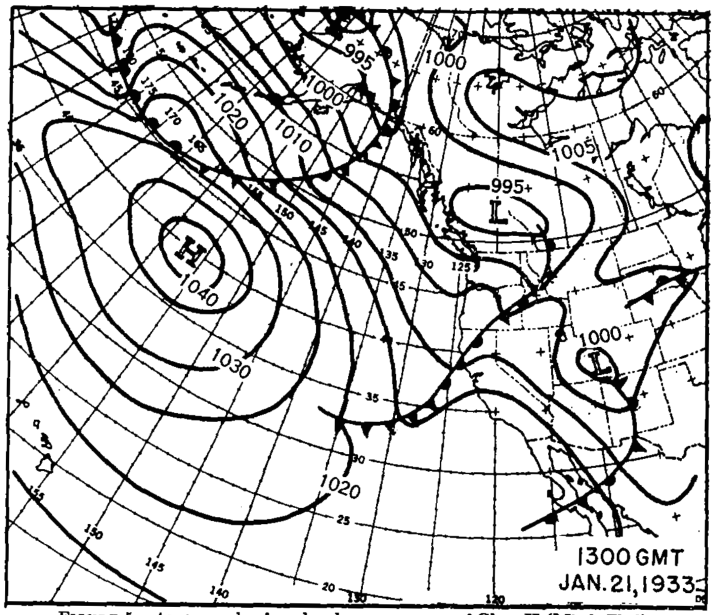

FIGURE 5.—An example of sea level pressure map of Class II (M>0, Z>0).

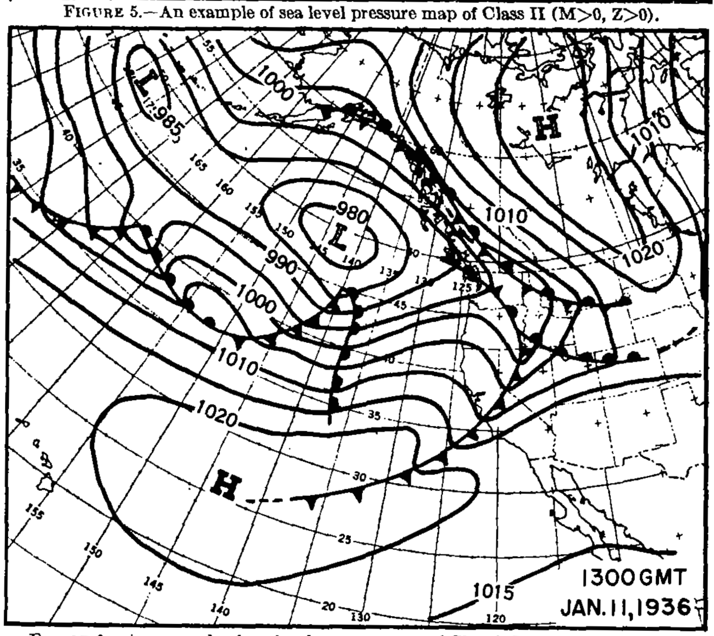

FIGURE 6.—An example of sea level pressure map of Class III (Z>0>M, Z>/M/).

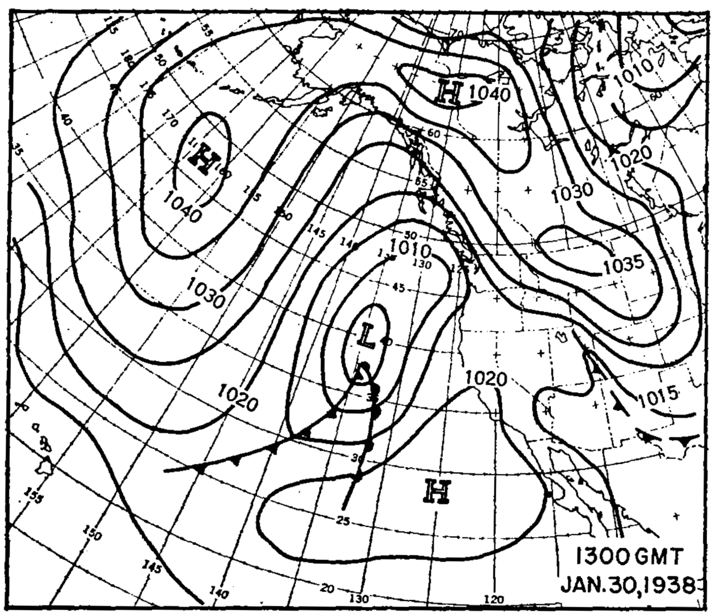

FIGURE 4.—An example of sea level pressure map of Class I (M>0>Z).

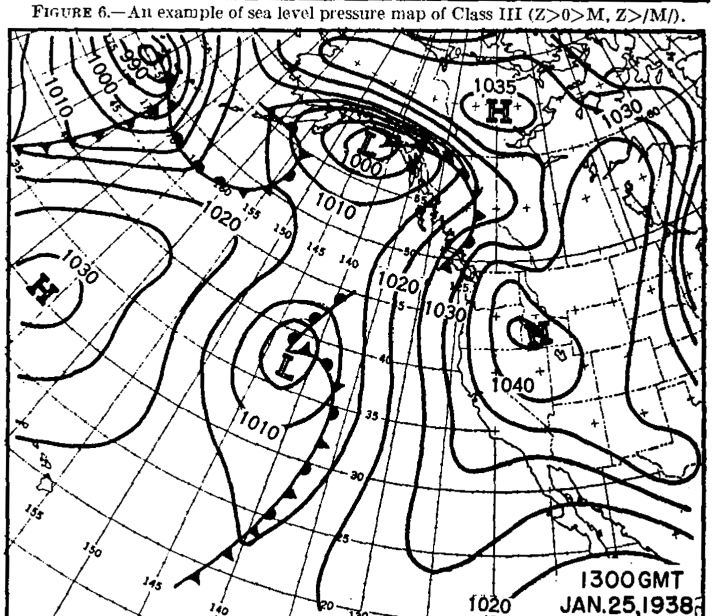

FIGURE 7.—An example of sea level pressure map of Class IV (0>M, /M/>/Z/).

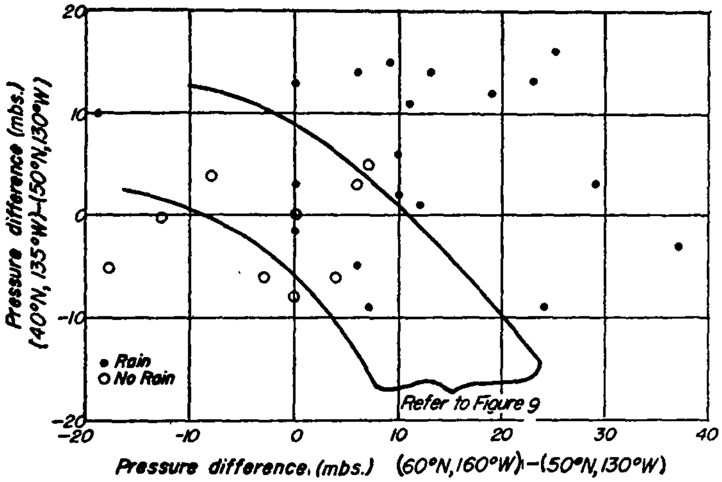


FIGURE 8.—Graph showing rain and no-rain cases from Class I maps plotted with 2 pressure difference variables as coordinates. Cases which fall within the heavy lines are further discriminated by replotting them against the coordinates shown in figure 9.

## SEPARATION OF RAIN AND NO-RAIN DAYS

The second step in the development of an objective method of forecasting rain at Portland was to find a means of separating the "rain" from the "no-rain" days within each class.

*Class I* ($M>0>Z$).—Maps of this class have characteristics of both "northerly" and "easterly" types (see fig. 4). The principal circulation of the air is from north to south. Pressure is lower over the coast than 500–1,000 miles offshore and usually there is a marked increase in pressure from Portland to the Alaskan Coast, a reversal of the normal distribution of pressure. The first attempt at finding a satisfactory method of segregating the "rain" and "no-rain" days was by correlating these pressure anomalies with the occurrences of rain at Portland. Strong pressure gradients between southwestern Alaska and Portland invariably produced rain. Examination of the data showed that there was a critical pressure difference between the points, 60° N., 160° W. and 50° N., 130° W. This pressure gradient proved to be a valuable variable in separating the "rain" and "no-rain" days.

The other important characteristic of this class is the low pressure trough which lies over the coast. There was a definite relation between rain at Portland and the position of this trough with respect to Portland. Any Lows within the trough were of less importance. Whenever the pressure at 50° N., 130° W. is higher than the pressure at 40° N, 135° W. the effective part of the trough has moved south of the latitude of Portland which is then out of the path of rain-bearing winds and rain terminates. In figure 8 all cases of Class I maps are plotted with these 2 pressure difference parameters as rectangular coordinates. There is no clear cut separation of "rain" and "no-rain" days, but one side of the graph is occupied almost wholly by "rain" days. Between this cluster of "rain" days and the few "no-rain" days on the opposite side there is a zone consisting of about an equal number of each kind of weather. These lines probably will require revision when more cases are studied inasmuch as there are only four cases on the "no-rain" side of the graph. Those cases in the transition zone were replotted using the pressure difference between 50° N., 130° W. and 50° N., 150° W. and the 24-hour pressure change

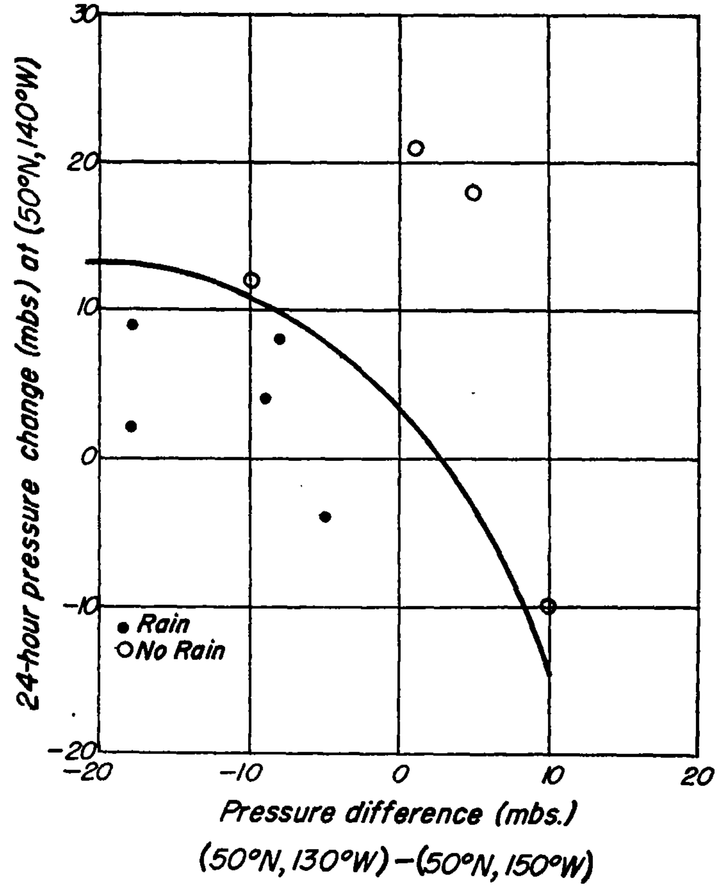


FIGURE 9.—Graph for use with cases which fall within the heavy lines of figure 8. These cases are here replotted against 2 secondary variables as coordinates.

at 50° N., 140° W. as coordinates (fig. 9). These two secondary variables further refine the characteristics of the low pressure trough and the high pressure ridge to the northwest. These variables should be used cautiously since there are too few cases to establish their validity.

*Class II* ($M>0$, $Z>0$).—This classification comprises the usual "northwesterly" types and a portion of those commonly called "northerly." The map in figure 5 borders between these two types but is representative of the maps in this classification. The distinguishing feature of this class as shown by figure 5 is the high pressure cell over the northeast Pacific with its axis oriented northwest-southeast. Its eastern periphery may extend inland over the coast but the center remains some distance from the coast. There may be two centers, one close to the California coast, and the other center farther out in the Pacific to the northwest. Fronts moving across the Aleutian Islands and over Alaska are steered southeastward by the major circulation around this High. This current of air becomes very unstable as it moves southeastward over the ocean and in the absence of fronts showery weather usually prevails at Portland. The scattergram, figure 2, shows that these maps produce rain in a vast majority of cases, 91 percent of those in this sample. No means were found by which the "no-rain" days could be separated from the "rain" days, probably because of the few days without rain compared to the number of days with rain. Thus, for Class II maps, the objective method always calls for a forecast of rain.

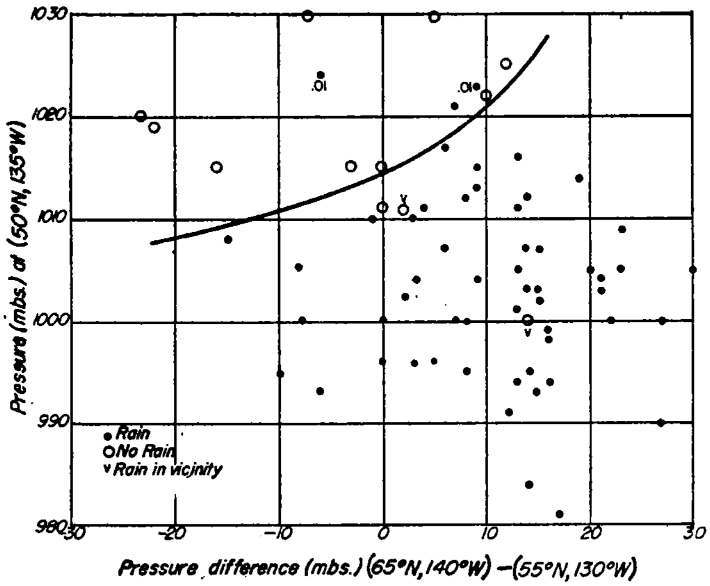


FIGURE 10.—Graph showing rain and no-rain cases from Class III maps plotted with 2 variables of the pressure field as coordinates.

*Class III* (Z>0>M, Z>/M/).—These are maps known as "southwesterly" types an example of which is shown in figure 6. There is a strong circulation from west to east with a weaker component toward the north. The High off the west coast usually shifts to the south or southwest just before the onset of rain. At times it merely weakens as another High appears farther west. There seemed to be a strong relationship between this High and the occurrence of rain at Portland but satisfactory results could not be obtained by using the location of the center of the High. The pressure along the northern edge of the High at the coordinate 50°N., 135°W., however, did give very good results. The pressure at this point was used as one of the coordinates in plotting cases for all maps of this class in figure 10. In the large sample rain occurred almost invariably whenever this pressure was near or lower than 1010 mbs. The effectiveness of the High off the coast in shielding Portland from rain is often offset by a High over northern Alaska. The probability of rain is greatly increased whenever there is a pressure gradient from central Alaska to the coast of British Columbia. When this gradient is reversed, southwest type Lows frequently recurve farther northward as they approach the coast and the probability of rain decreases. The pressure gradient between the points 65° N., 140° W. and 55° N., 130° W. brought out this feature of the maps and was used as the second variable in figure 10. Of the 56 cases below the curve in figure 10, only three failed to produce rain, but, in two of these, rain fell in the vicinity of Portland.

*Class IV* (0>M, /M/>/Z/).—Southerly maps are the only type discussed in this paper which produced more days without rain than with rain. To a large extent the pressure distribution is the reverse of the first class discussed. Typical southerly maps (fig. 7) are characterized by a broad trough of low pressure several hundred miles off the west coast. A series of storms begins in this trough and each storm moves in a northerly direction. During the period of formation and movement of these storms

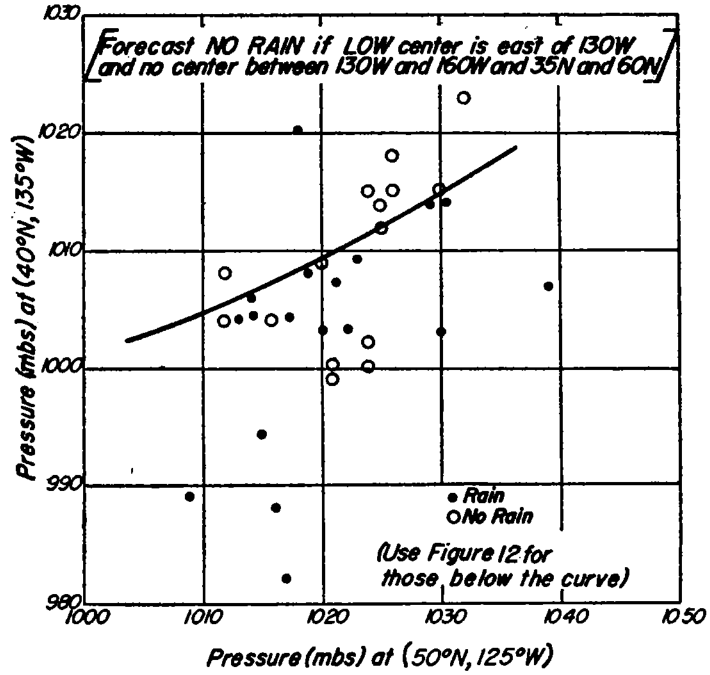


FIGURE 11.—Graph showing rain and no-rain cases from Class IV maps having lows centered within the area 130° to 150° W. and 30° to 45° N. These cases are plotted against 2 pressure variables as coordinates. See figure 12 for further stratification of cases which fall below the curve.

the trough advances slowly eastward and produces rain as it nears the coast and moves onshore. Another distinguishing feature of these maps is the high pressure over the coast and Far West in contrast to low pressure over that area in a "northerly" type. Because these Lows move northward and generally reach Portland only in the late phase of the type, the occurrences of rain are less frequent. Many times in the past rain was forecast much too early in these situations.

These maps were the most difficult to deal with and at this stage of the study the results are less satisfactory than those obtained with other classes. The trough of low pressure which is the dominant feature usually extends over 30 degrees of latitude. This made it necessary to separate the maps into three groups to obtain the best results. One group consisted of maps with Lows centered in the area from latitude 45° N. to 30° N. and from longitude 150° W. to 130° W. For these Lows the pressures at the points 50° N., 125° W. and 40° N., 135° W. measured the gradient offshore and to a large extent measured the intensity of the trough. These two variables were used as coordinates in plotting figure 11. On this graph a line was drawn, above which most of the cases were "no-rain". However, a search for two additional variables was required to further stratify the cases below the line. The pressure difference between 40° N., 130° W. and 40° N., 160° W. usually covered the breadth of the trough and it showed some relationship to rain. Another variable which was more significant than many others tried was the pressure gradient north to south across the western part of the Plateau (pressure difference between 50° N., 115° W. and 35° N., 115° W.). The results of using these variables as coordinates in plotting the cases below the curve (fig. 11) are shown in figure 12. In

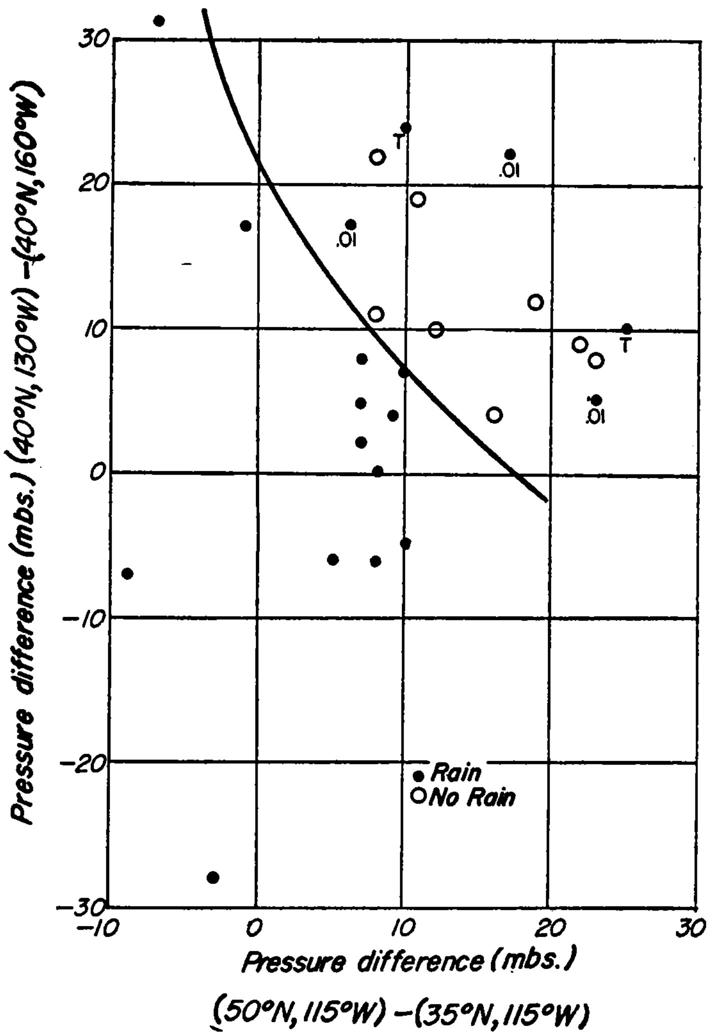


FIGURE 12.—Graph for use with cases which fall below the curve in figure 11. These cases are here replotted against 2 secondary variables as coordinates.

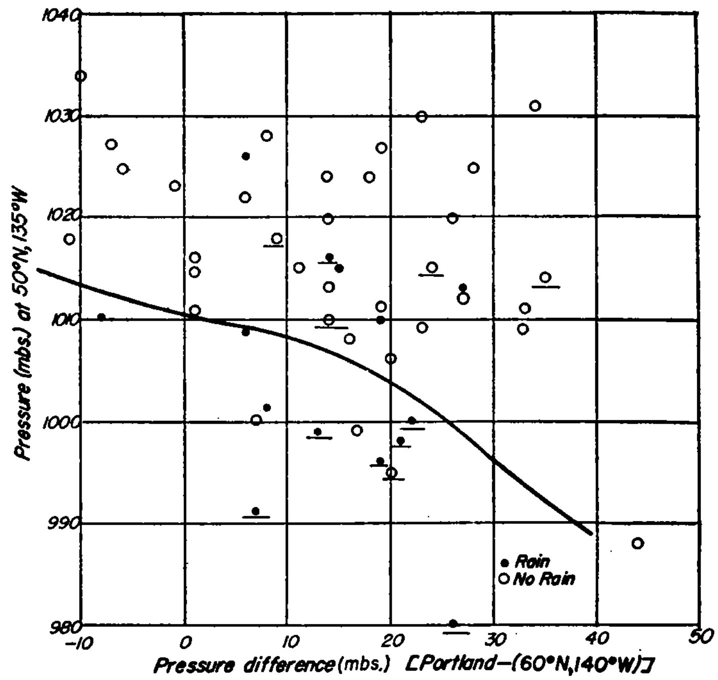


FIGURE 13.—Graph showing rain and no-rain cases from Class IV maps having a low center between 45° and 60° N. or at any latitude west of 150° W. These cases are plotted against variables of the pressure field as coordinates. Cases having lows between the coast and 150° W. and north of 45° N. are underlined.

figure 12, the five misses on the "no-rain" side of the curve are not too discouraging since each map produced only a trace, or .01 inch, of rain.

The second group of maps were those with Lows between 45° N. and 60° N. and those with Lows at any latitude west of longitude 150° W. On the east side of the low pressure trough which is common to a southerly type, the isobars lie roughly along the meridians. The pressure difference between Portland and the point 60° N., 140° W. was found to give a satisfactory indication of the strength of the southerly flow along the coast and was chosen as the first variable for plotting figure 13 for this group of maps. When the pressure decreases at a faster rate at 60° N., 140° W. than it does at Portland, the southerly flow becomes stronger and the tendency for Lows to follow a northward course and pass inland north of Portland increases.

The absolute pressure at the point 50° N., 135° W. was selected as the other variable for plotting figure 13. This variable gives some measure of the intensity of the trough and its location or movement. When the trough nears the point the rain area usually extends over Portland within 48 hours. Low pressure at the point indicates that the trough (or Low) is approaching the coast, whereas high pressure indicates that the high pressure system, which is found over the west coast in a southerly type, still dominates the coastal weather.

It will be seen from figure 13 that on southerly maps with Lows west of 150° W. the stratification of "rain" and "no-rain" cases was not entirely satisfactory. This suggests that in any revision of this method, these maps may have to be treated separately as it may be that the original points chosen for typing maps will require revision whenever there is a negative meridional circulation.

Frequently there were Class IV maps with Lows in both areas upon which the above two groupings depend. Each such case was treated individually according to procedures for both groups. In tests it was found advisable to forecast rain if the objective forecast of either group indicated rain.

The final group of southerly maps were those with a low center east of 130° W. and no center from 130° W. to 160° W. and from 35° N. to 60° N. Lows centered east of 130° W. were moving onshore and none in the sample produced rain. Thus, for this group of Class IV maps the objective method always calls for a forecast of "no-rain."

*Class V* (0>M>Z).—Maps in this class may be similar to figure 7 except that usually only the southernmost Low is present and the two large Highs meet north of this low pressure center. There were only 6 maps of this class in the total of 297 maps of the original sample and only 3 in the 121 maps on which tests were made. Because the cases in the sample were too few to permit obtaining significant results, no forecasting technique was developed. Therefore, it is merely noted in passing that there were 2 "rain" days and 4 "no-rain" days in the original sample and 3 "rain" days and no "no-rain" days in the test sample.

## VERIFICATION

### ORIGINAL CASES

Verification of forecasts made by the objective method for classes I, II, III, and IV of the original cases used in developing the system is given in table 1.

TABLE 1.—*Verification of forecasts for original cases.*

| CLASS I | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| Observed | Rain | 19 | 0 | 19 | Percent correct=97 |
| | No rain | 1 | 8 | 9 | Skill score [1]=.92 |
| | Total | 20 | 8 | 28 | |

| CLASS II | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 96 | 0 | 96 | Percent correct=91 |
| | No rain | 10 | 0 | 10 | Skill score=.77 |
| | Total | 106 | 0 | 106 | |

| CLASS III | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 52 | 3 | 55 | Percent correct=91 |
| | No rain | 3 | 12 | 15 | Skill score=.81 |
| | Total | 55 | 15 | 70 | |

| CLASS IV | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 22 | 11 | 33 | Percent correct=84 |
| | No rain | 3 | 51 | 54 | Skill score=.70 |
| | Total | 25 | 62 | 87 | |

| CLASSES I, II, III AND IV. | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 189 | 14 | 203 | Percent correct=89 |
| | No rain | 17 | 71 | 88 | Skill score=.77 |
| | Total | 206 | 85 | 291 | |

[1] The skill score, $S_c$, in this study is defined by

$$S_c=\frac{C-E_c}{T-E_c}$$

where $C$=number of correct forecasts,
$E_c$=number of forecasts expected to be correct due to chance, and
$T$=total number of forecasts.

It has a value of unity when all forecasts are correct, and zero when the number of correct forecasts is equal to the number expected to be corrected due to chance. In this study, the number of forecasts expected to be correct by chance is defined as the number expected correct from an equal number of random forecasts of rain days and no-rain days, with the proportion of rain days to no-rain days in accordance with climatological averages for the forecast period. Hence, the number of forecasts expected to be correct on this basis may be determined by

$$E_c=R\times f_r+N(1-f_r),$$

where $R$=observed number of rain days,
$N$=observed number of no-rain days, and
$f_r$=relative frequency of occurrence of rain days during the period covered by forecasts, determined from climatological data (Ex: If during January and February, 59 days, it rains on the average 37 days, $f_r$ would be 37/59).

### INDEPENDENT CASES

To subject this system of forecasting to a test in cases independent of those used in the investigation, the months of January and February 1937, and December 1930, and 1933, were selected. A preconception was that the weather regime at Portland in December is normally about the same as in January and February. These four months were chosen arbitrarily although the total days with rain was 27 percent above the average as shown in the following table. In December 1933 rain fell on every day. On the other hand December 1930 had the normal number of rainy days but the total precipitation for the month was abnormally low. The skill score over the Climatological forecasts and the percentage of hits were just a little higher in the two Decembers than in the January and February test months. Other tests made from day to day during the winter 1947–1948 gave results comparable to those of the test months.

A break-down of the maps in the four test months was as follows:

| Class | Number of maps | Rain days | No-rain days |
|---|---|---|---|
| I | 27 | 18 | 9 |
| II | 33 | 28 | 5 |
| III | 41 | 32 | 9 |
| IV | 17 | 12 | 5 |
| V | 3 | 3 | 0 |
| Total | 121 | 93 | 28 |

Verification of forecasts made from these independent data for December 1930 and 1931, and January and February 1937 gave the results indicated in table 2.

TABLE 2.—*Verification of forecasts for independent cases*

| CLASS I | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 16 | 0 | 18 | Percent correct=85 |
| | No rain | 4 | 5 | 9 | Skill score=.69 |
| | Total | 22 | 5 | 27 | |

| CLASS II | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 28 | 0 | 28 | Percent correct=85 |
| | No rain | 5 | 0 | 5 | Skill score=.64 |
| | Total | 33 | 0 | 33 | |

| CLASS III | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 28 | 4 | 32 | Percent correct=83 |
| | No rain | 3 | 6 | 9 | Skill score=.61 |
| | Total | 31 | 10 | 41 | |

| CLASS IV | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 9 | 3 | 12 | Percent correct=82 |
| | No rain | 0 | 5 | 5 | Skill score=.62 |
| | Total | 9 | 8 | 17 | |

| CLASSES I, II, III, AND IV | | Forecast: Rain | No rain | Total | |
|---|---|---|---|---|---|
| OBSERVED | Rain | 83 | 7 | 90 | Percent correct=84 |
| | No rain | 12 | 16 | 28 | Skill score=.63 |
| | Total | 95 | 23 | 118 | |

## CONCLUSIONS

1. The method of forecasting described here is highly objective. It can reduce differences of opinion as to map types and reduce the number of differing forecasts. However, it should be used as an aid to rather than as a substitute for the usual forecasting precepts. Study of additional maps is necessary in order to either confirm the results in this paper or to develop more efficient parameters.
2. Although data are based on 1300 GMT maps experience has shown that satisfactory results can be obtained with maps for other times of the day.
3. In this method of determining map types by mathematical relationships between circulation indices, successive 6-hourly maps may fluctuate between two or even three types when one or both indices are small. The movement of a Low or a small High across one of the key coordinates will cause a fall and rise of several millibars within the course of a day. This results in a slight change in one of the indices, but often the change is sufficient to shift the maps from one type to another when maps are only six hours apart. In such cases it is advisable to assume the original type unless there is evidence that the change in type is permanent.
4. From forecasts made by this method from successive 6-hourly maps the time of beginning and ending of rain often can be anticipated within a few hours. This manner of timing can be useful when the location or speed of fronts cannot be determined, and useful also during periods of shower activity.
5. Whenever the objective forecast is strongly opposed to the forecast obtained in the usual manner it is advisable for the forecaster to examine the maps more carefully and review his reasoning. In day-to-day tests four instances of this kind are recalled. A reevaluation of the data on the maps revealed evidence of phenomena which would cause rain, and the original analyses were revised. Reports were scarce and the little data had to be weighed carefully, nevertheless these phenomena were borne out by subsequent charts.

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# ADDITIONAL TESTS OF COUNTS' OBJECTIVE METHOD OF FORECASTING WINTER RAIN FOR PORTLAND, OREGON

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The Weather Bureau District Forecast Staff at Seattle, Washington, made practical use of Counts' objective method of forecasting precipitation for the second day in advance at Portland, Oregon, during the winter season of 1948–49. In the application of the method, the Seattle Staff rigidly followed the rules set forth by Counts, except that the forecast period was considered to be 24–48 hours after map time instead of 20–44 hours used by Counts; for the purpose of this test no attempt was made to improve the forecasting results by following suggestions contained in his article. A record of the M and Z values for the 0030 GMT and 1230 GMT maps was kept during the months of November, December, January, February and March. Each case was immediately classified and the forecast obtained from the scatter diagrams was recorded and also used by the staff forecaster as an aid in making the official forecast.

There were 302 maps used in the test and they were segregated as follows:

| Class | Number of maps | Rain days | No-rain days |
|---|---|---|---|
| I | 26 | 18 | 8 |
| II | 133 | 113 | 20 |
| III | 72 | 48 | 24 |
| IV | 61 | 27 | 34 |
| V | 10 | 2 | 8 |
| Total | 302 | 208 | 94 |

The ratio of "rain" days to "no-rain" days is very nearly the same as found in Counts' original investigation of 297 cases. The greater number of Class II cases and fewer Class IV cases in the present test compared to the original study is very noticeable.